



Canadian SMAP Workshop

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L4 Carbon Algorithm & Test Status

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L4_C Science Requirements & Traceability

SMAP science objectives addressed:

- Quantify net ecosystem exchange (NEE) of CO₂ in boreal landscapes;
- Improve understanding of processes linking terrestrial water, carbon & energy cycles;

Product requirements:

- Determine NEE daily, seasonal & annual variability & heterogeneity within & among major biome types;
- Link NEE with component C fluxes (GPP, R) & primary soil moisture & thermal constraints to productivity & ecosystem respiration;

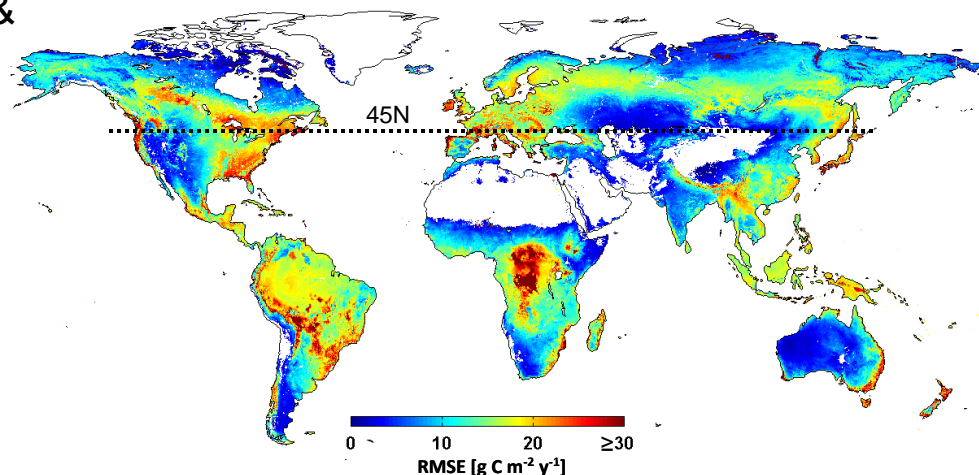
Product success criteria:

- Emphasis on northern ($\geq 45^\circ\text{N}$) land areas;
- NEE accuracy (RMSE) commensurate with tower based C-fluxes for major biome types.

L4_C Error Budget (RMSE)

Type of Error	Error Source	Source Units	Range	Value	NEE Contribution (g m ⁻² y ⁻¹)
Input Data	Temperature	deg C	1.5-4	3.5	6.2
	Moisture	vol. m ³ /m ³	0.04-0.10	0.05	5.7
	GPP	g m ⁻² d ⁻¹	1.0-2.0	1.5	14.5
Model Parameterization	Optimal Decomp. Rates/Response	d ⁻¹	0.001-0.01	0.005	2.9
	Pool Representation/Steady State	g m ⁻²	100-1000	1000	9.6
	Autotrophic Respiration fraction	dim	0.05-0.15	0.1	2.7
Heterogeneity	Land Cover Heterogeneity	g m ⁻² yr ⁻¹	0-60	16	22.6
Total NEE Error	Inputs Only	g m ⁻² yr ⁻¹			16.7
	Model Only	g m ⁻² yr ⁻¹			10.4
	Inputs + Model	g m ⁻² yr ⁻¹			19.7
	Inputs + Model + Het.	g m ⁻² yr ⁻¹			30.0

L4_C Estimated NEE Error (RMSE)





SMAP L4_C Product Summary

Net Ecosystem CO₂ Exchange (NEE)

Motivation/Objectives: Quantify NEE variability for major biomes; Link NEE to primary moisture & thermal constraints to productivity & ecosystem respiration

Approach: Apply LUE & soil Decomp. Algs. driven by SMAP & other ancillary inputs

Inputs: FT (L3_SM_A); SM & T (L4_SM); Rs, VPD, Tmn (GMAO); FPAR (MODIS, VIIRS)

Outputs: NEE (validated); GPP, Rh, SOC, EC & QC metrics (research)

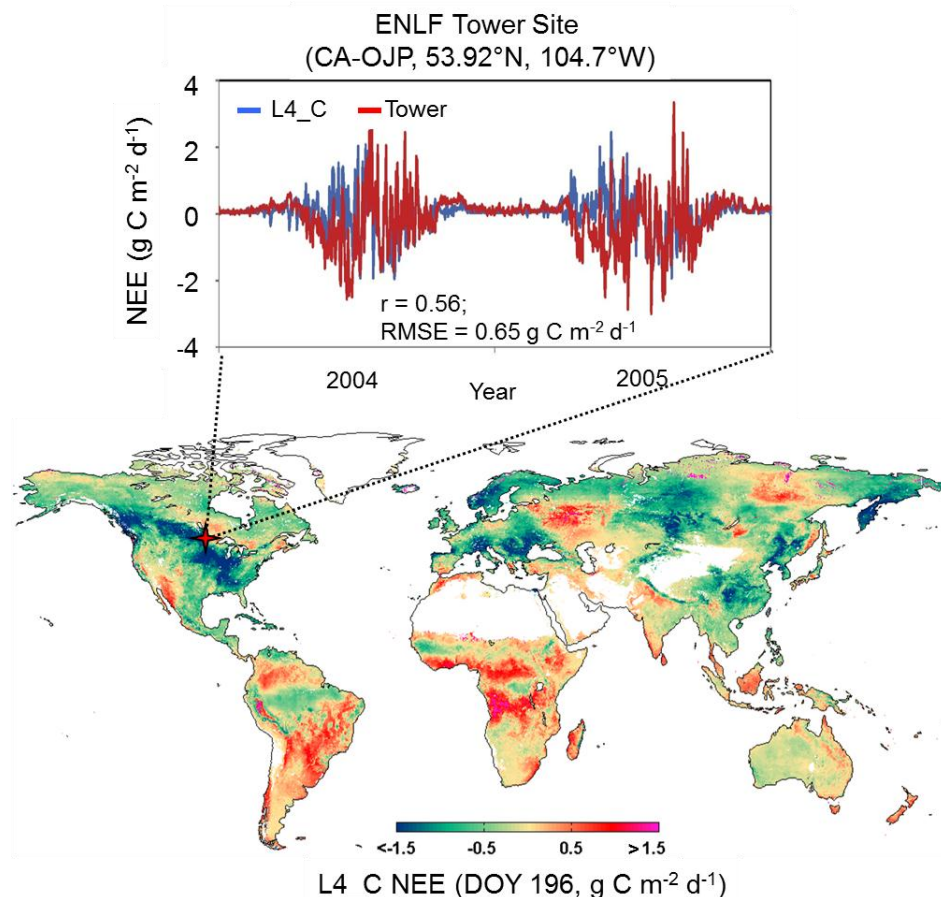
Domain: Global vegetated areas

Resolution: 9 km (1 km processing)

Temporal fidelity: Daily

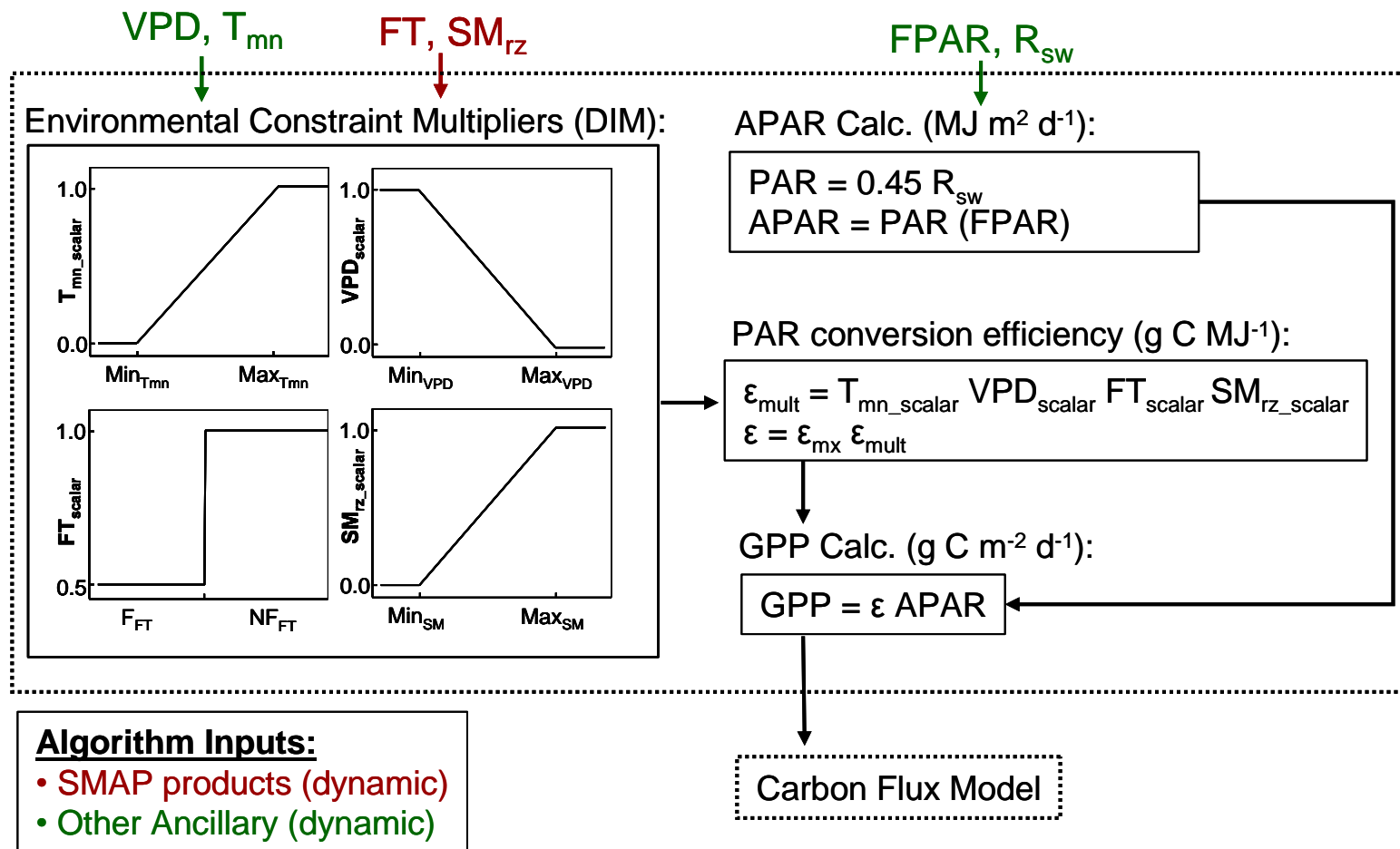
Accuracy: Emphasis on boreal land areas; NEE RMSE $\leq 1.6 \text{ g C m}^{-2} \text{ d}^{-1}$ relative to tower observations

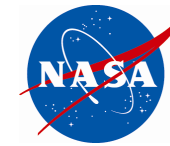
L4_C Product Example



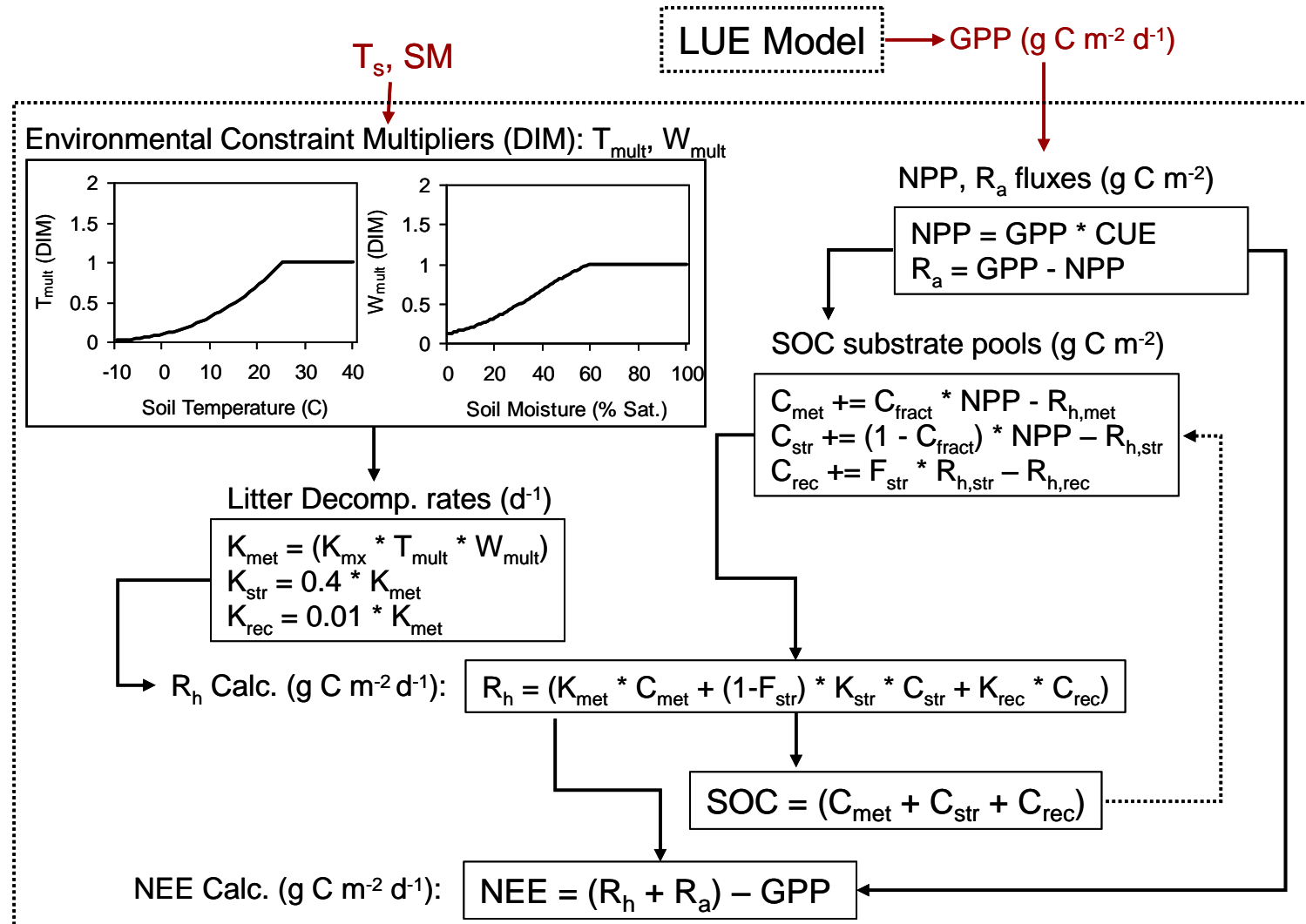


L4_C GPP Calculation





L4_C Carbon Flux Algorithm

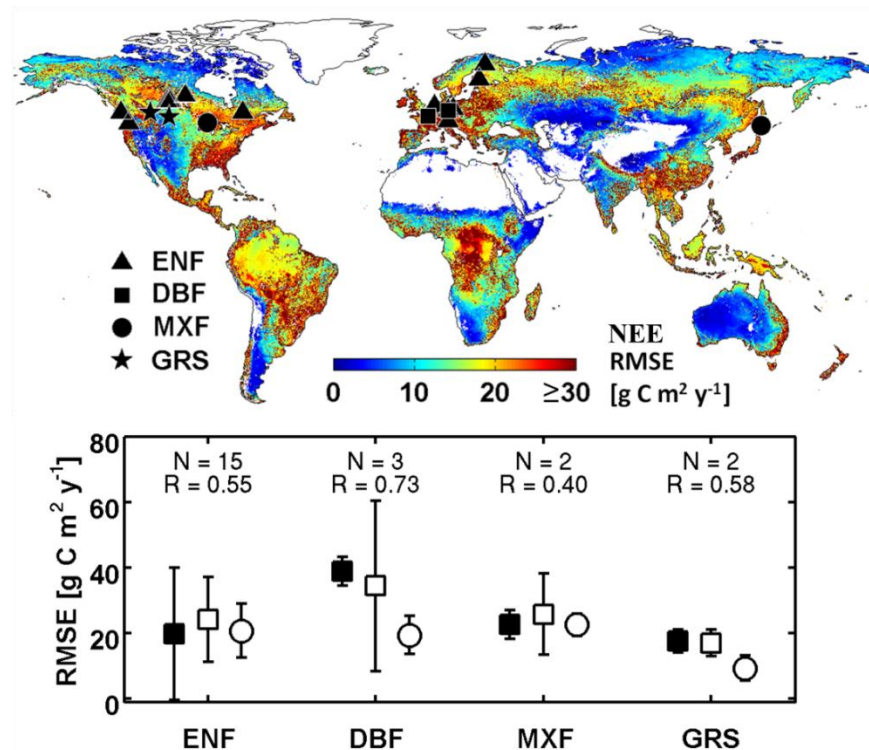


Pre-launch Cal/Val Activities

Emphasis: model performance evaluation, calibration, initialization;

- Site, region & global L4_C simulations using tower (FLUXNET), satellite (MODIS) & reanalysis (MERRA) drivers;
 - ✓ Quantify expected global performance & uncertainty (e.g. mean & variability, QC range thresholds);
- Model calibration (BPLUT) & consistency checks using tower data & synergistic global C products (MOD17, MTE, SOC inventories);
- Model initialization & assembly of ancillary data for post-launch operations (SOC pools; FPAR climatology; QC/QA base maps).

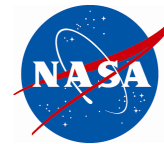
Estimated L4_C NEE Annual Error relative to Tower Observations



Source: Jones et al. 2013 In prep.

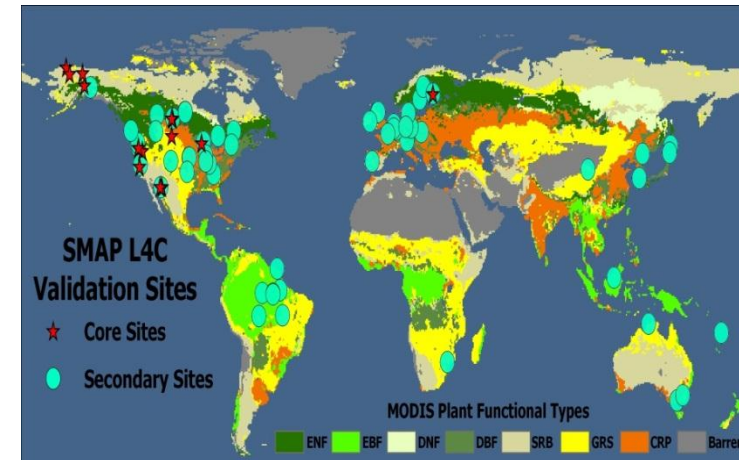


Ancillary Data Resources for Validation

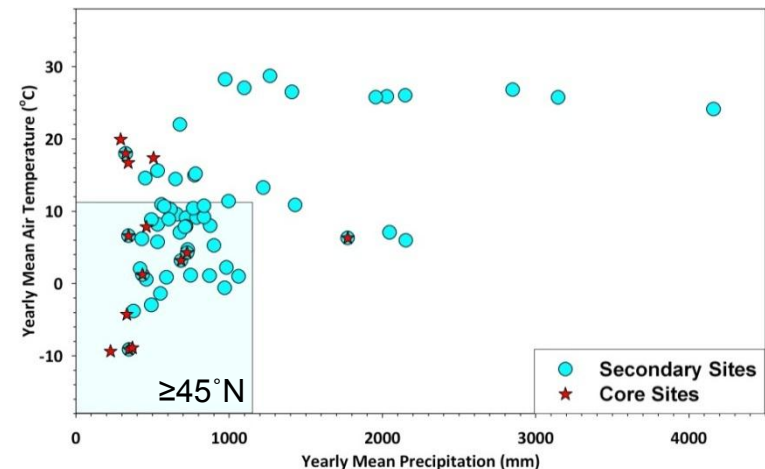


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- ✓ **Core tower sites providing daily C-fluxes & supporting data**
 - ~17 sites emphasizing northern biomes
 - Meet Cal/Val site requirements
 - Formal agreements for near real-time data access
- ✓ **Secondary sites meeting validation criteria from global FLUXNET archives**
 - ~80 (from >400) sites; global representation
 - Multi-year records, consistent methods, well characterized uncertainty, but not real-time
- ✓ **Synergistic global land products**
 - L4_C simulator outputs
 - MODIS GPP
 - Soil Carbon (SOC) inventories [static]
 - Upscaled, Obs. based C products (MTE)



L4_C Validation Sites in Climate Space

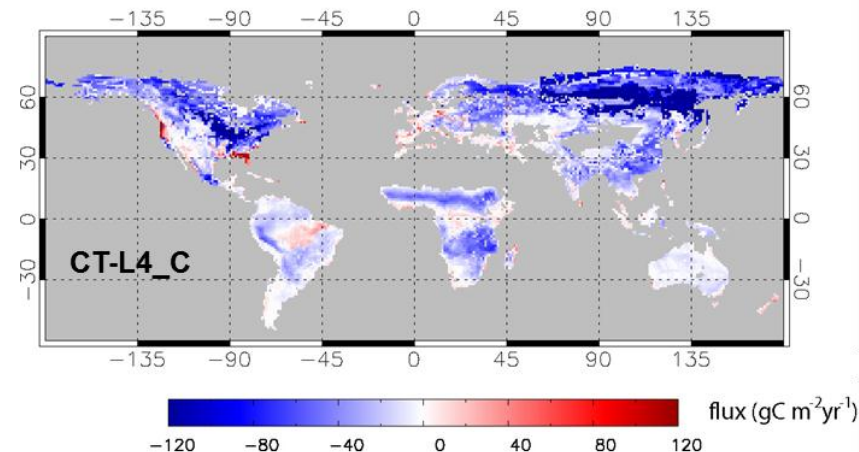


Pre-launch Cal/Val Activities

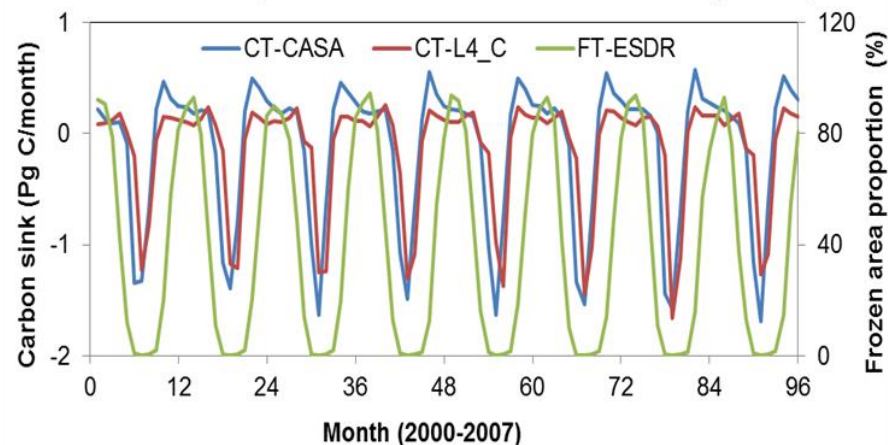
L4_C Science Application Demonstration: Quantify terrestrial carbon (CO₂) source-sink activity

- L4_C outputs as land surface priors for top-down Atm. carbon model inversions (e.g. CarbonTracker);
- Validation enhancement using synergistic C observations (CO₂ flask network, OCO-2);
- Links C source/sink activity to NEE & underlying SM & thermal constraints (SMAP Decadal Survey objective);

Mean Annual CO₂ Source / Sink Activity
(CarbonTracker, 2000-2007)



CT Monthly Land Fluxes and Frozen Area ($\geq 50^\circ\text{N}$)

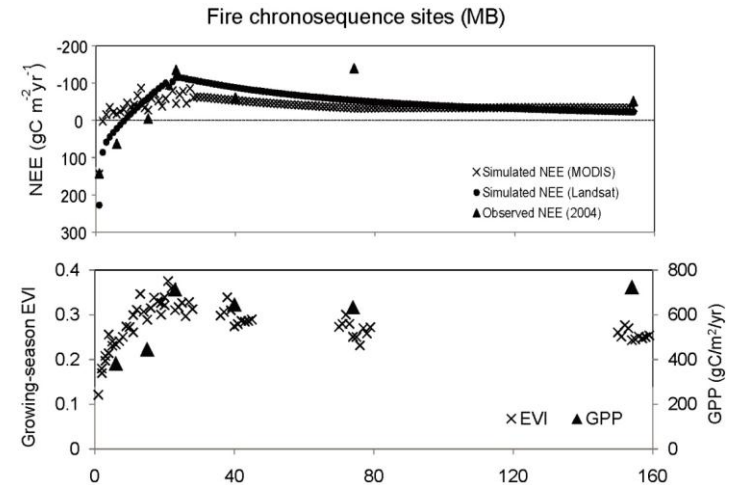




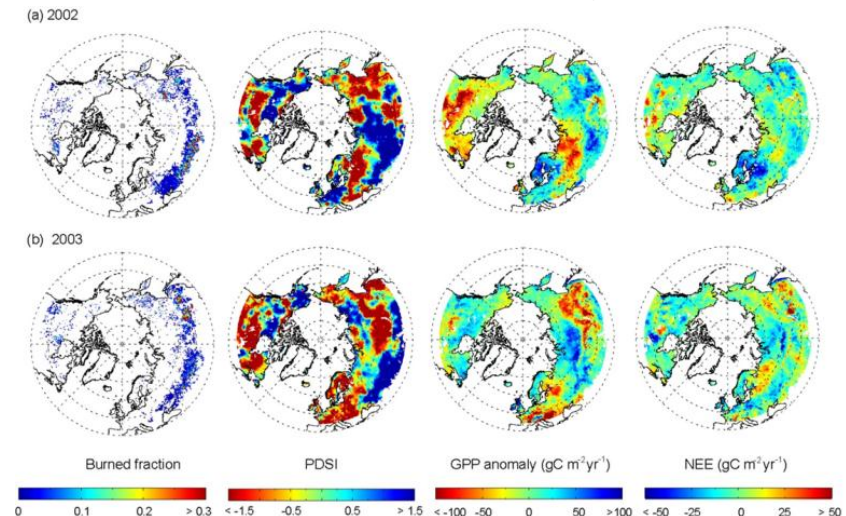
Pre-launch Cal/Val Activities

L4_C options refinement & downselect:

- Two L4_C options represented:
 - ✓ Dynamic FPAR estimation from lower order VI inputs;
 - ✓ Fire disturbance recovery;
- Downselect criteria: Balance accuracy & science utility against operational efficiency & reliability
 - ✓ Accuracy & reliability for global implementation;
 - ✓ MODIS operational status & VIIRS land product (VVI) development;



TCF response to fire (GFED) & drought variability



Source: Yi et al. 2013. JGR



L4_C Cal/Val Rehearsals



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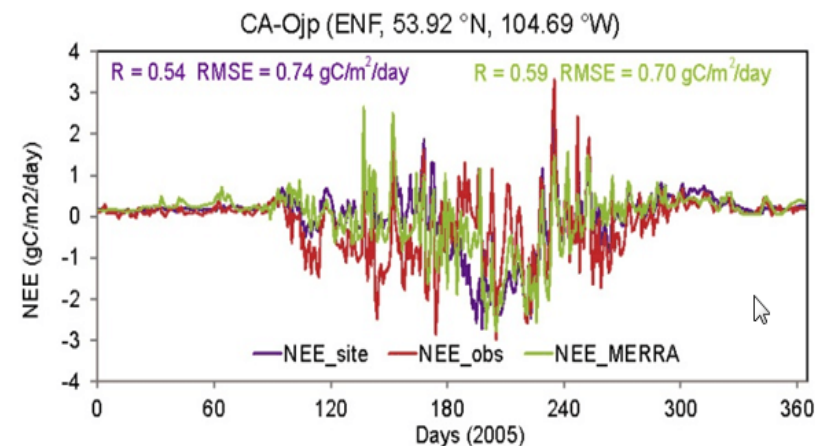
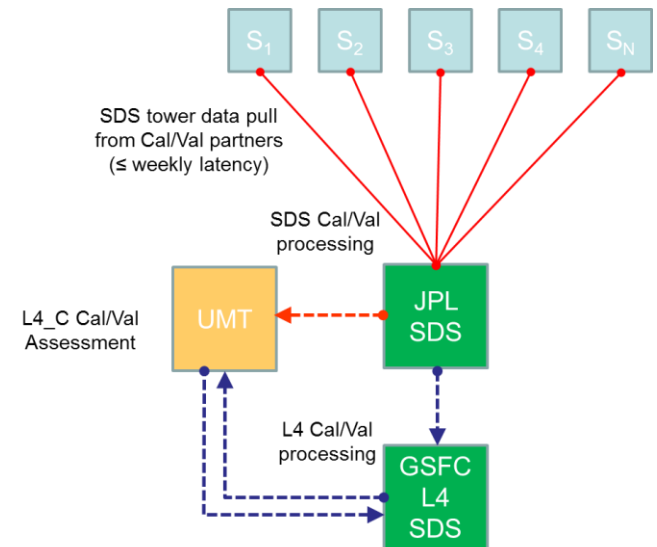
Motivation: Test mission software & Cal/Val partner capabilities to provide near real-time tower data in an appropriate & consistent format;

Phase 1 (Jun-Aug 2013):

- Involve a subset of core tower validation sites;
- Compare preparatory L4_C Alg. simulations & daily tower observations co-located in space, but not in time;
- Metrics: Data latency & consistency checks, RMSE, MRE, Correlation analysis;

Phase 2 (Apr-May 2014):

- Involve all (17) core tower sites;
- Use mature L4_C Alg. software for comparisons:
 - Comparisons co-located in space but not in time;
 - Tower footprint vs 1-9 km Res. outputs;
 - Model sensitivity runs to distinguish relative error sources.





Post-launch Cal/Val Activities

Primary (post-IOC period):

- L4_C recalibration, reinitialization using SMAP operational data;
- NEE daily product comparisons against core tower site observations;
- Operational checks against QC range thresholds;

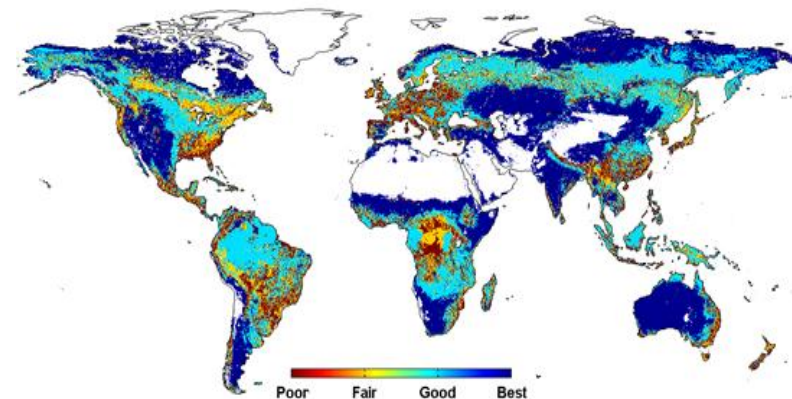
Secondary:

- Verify other L4_C parameters (GPP, R, SOC, EC, QC);
- L4_C global sensitivity & performance analysis;
- Consistency checks against other global C products;

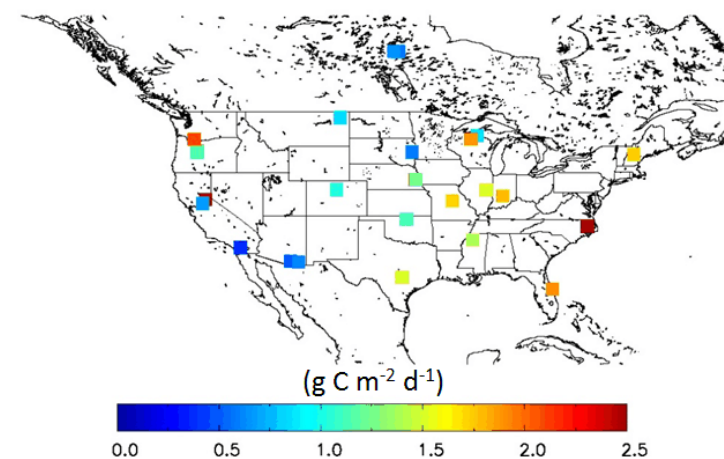
Actions taken (if needed) to meet performance criteria:

- Subject to science (ADT) team & SDS change control board.

NEE Product Quality (QC)



NEE RMSE





Potential Carbon Collaborations

- Core tower validation site partnerships;
- Coordinated carbon product comparisons & benchmarking activities;
- Field campaigns (e.g. ¹ABoVE)
- Algorithm refinement & sensitivity studies:
 - ✓ Wetlands & permafrost landscapes;
 - ✓ Disturbance recovery effects;
 - ✓ Agricultural landscapes;
 - ✓ Carbon & climate feedbacks;
- Science application demonstrations & development
 - ✓ National carbon assessments



¹Source: http://cce.nasa.gov/terrestrial_ecology/pdfs/ABoVE%20Final%20Report.pdf